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Comparison of the results of computerized tomography of the hips in adult patients with unilateral high hip dislocation

Comparison of hips in patients with unilateral dislocation

Ahmet Atilla Abdioğlu[1], Servet Kerimoğlu[2], Ali Küpeli[3], Polat Koşucu[4]
[1] Department of Orthopedics and Traumatology, Fatih State Hospital
[2] Department of Orthopedics and Traumatology, Faculty of Medicine, Karadeniz Technical University
[3] Department of Radiology, Kanuni Education and Research Hospital
[4] Department of Radiology, Faculty of Medicine, Karadeniz Technical University, Trabzon, Turkey

Abstract
Aim: Since the joints of adult patients with developmental dysplasia of the hip (DDH) differ significantly from normal anatomy, surgery in these patients poses many additional challenges. The aim of this study was to quantify the anatomical differences between the hips of individuals with normal hips on one side and high hip dislocation on the other side.
Material and Methods: Twenty computed tomography images of unoperated patients with one normal hip and one high hip dislocation (Hartofilakidis type C) were retrospectively analyzed. The acetabulum was analyzed with seven measurements and the femur with 16 measurements.
Results: The mean acetabular volume of the normal side was 2.3 times that of the dislocated side, the depth was 1.5 times that of the dislocated side, the anteroposterior diameter was 1.58 times that of the dislocated side, and the mean posterior lip thickness was 3.61 times that of the dislocated side. The femoral cortical thickness of the dislocated hip was thinner, the femoral anteversion angle was higher and the trochanter minor was more retroverted than the normal side. Although the total length of the dislocated side was less, we observed that the femur of the dislocated side was longer distally than the trochanter minor.
Discussion: Patients with unilateral high DDH had significant changes in both the acetabulum and the intact side. We recommend a thorough pre-assessment and preparation to prevent complications during total hip arthroplasty surgery as part of DDH treatment.

Keywords
Developmental Hip Dysplasia, Dislocation Height, Hartofilakidis Type C, Computed Tomography, Total Hip Arthroplasty

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Corresponding Author: Ahmet Atilla Abdioğlu, Department of Orthopedics and Traumatology, Fatih State Hospital, 61100, Trabzon, Turkey.
E-mail: ahmetatilla@hotmail.com P: +90 505 925 31 87
Corresponding Author ORCID ID: https://orcid.org/0000-0002-0206-8135
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Introduction

Developmental dysplasia of the hip (DDH) is a broad term that encompasses all problems ranging from hip instability to total dislocation, in which the femoral head-acetabulum connection is completely lost [1,2]. Various classification systems exist for DDH [3,4].

In populations subjected to standard postnatal ultrasonography screening, the incidence of dysplasia ranges from 25 to 50 per 1000 [1,5]. Although DDH can be detected and treated early using advanced screening, diagnosis, and treatment procedures, it is a health concern that can cause major complications for the patient if not detected and addressed [1,5]. Patients with untreated DDH are more likely to develop osteoarthritis in the affected hip joint [6]. DDH can result in symptoms such as discomfort, limited movement, limb length inequality, and limping [3,6]. Since the tissues of patients with osteoarthritis secondary to DDH differ greatly from normal hip anatomy, the surgeries to be undertaken in the treatment provide numerous extra challenges [3,7-9].

The goal of our study was to use quantitative data to identify the anatomical differences between the two hips in patients with unilateral DDH and to gain a better understanding of the difficulties that might arise during treatment.

Material and Methods

The study included patients who were advised to undergo computed tomography (CT) conducted for the purpose of planning prior to total hip arthroplasty (THA) surgery at the Orthopedics and Traumatology clinic within a year. The study was approved by the ethics committee of Karadeniz Technical University Faculty of Medicine on 08.04.2013 with the number 2013/19 and informed consent was obtained from the patients. Twenty hips from ten different patients were evaluated.

The study comprised patients with high hip dislocation in just one hip joint (Hartofilakidis classification Type C) and no disease in the other hip joint. Patients over the age of 18 with no other systemic diseases were included. None of the patients underwent orthopedic surgery. Multislice computed tomography images were obtained using "Siemens Somatom Plus" and "Toshiba Prime Aquilion TSX-303A". The imaging was obtained with the patient in a supine position, with the patella facing the ceiling. The cross-sectional area was measured from the level of the superior crista iliaca to the distal femoral articular surface. Sections were taken every 1 millimeter. Coronal and sagittal reconstruction pictures were created from the axial plane images. The measurements were obtained from these images. Dislocated hip measurements were taken from actual acetabulum. Each patient's measurement was repeated three times by the same radiologist, randomly and blinded to patient information. To acquire precise results, each patient's measurements were obtained three times, and the arithmetic average of the data was taken. Units used were millimeters for length, degrees for angles, and cubic centimeters for volume.

Femoral measurements (FM): distance from femoral head to trochanter minor (FM1), distance between trochanter major and intercondylar notch (FM2), distance between femoral head and intercondylar notch (FM3), femoral anteversion angle (FM4), angle of the trochanter minor long axis relative to the femoral condyles (FM5), anteroposterior canal diameter at half the distance between the trochanter major notch (FM6), diameter of the medio-lateral canal at half the distance between the trochanter major notch (FM7), anteroposterior canal diameter at the level where the trochanter minor is most protruding (FM8), diameter of the medio-lateral canal at the level where the trochanter minor is most protruding (FM9), antero-posterior canal diameter at the level of the proximal quarter of the distance between the trochanter major notch (FM10), diameter of the medio-lateral canal at the level of the proximal quarter of the distance between the trochanter major notch (FM11), the narrowest canal diameter of the femur (FM12), distance from the narrowest canal diameter of the femur to the minor (FM13), average cortical thickness 2 cm distal to the trochanter minor (FM14), diameter of the antero-posterior canal 2 cm distal to the trochanter minor (FM15) and diameter of the medio-lateral canal 2 cm distal to the trochanter minor (FM16) [12-15,25].

Acetabulum measurements (AM): acetabular anteversion angle (AM1), acetabulum depth (AM2), anteroposterior diameter (AM3), medial bone thickness (AM4), anterior lip thickness (AM5), posterior lip thickness (AM6) and acetabulum volume (AM7) [10,11,20-24].

The acetabular anteversion angle (AM1) was measured in axial sections by drawing a line perpendicular to the line joining the most posterior ends of the iliac bones and crossing it through the anterior and posterior lip tips at the level where the real acetabulum is deepest [10,11].

The patients' axial images were transferred to the Vizard and Vitrea workstations. Images of 3D volume rendering coronal and sagittal reconstruction were created. The acetabular fossa's borders were delineated in the axial, coronal, and sagittal planes on these pictures, and its volume (AM7) was estimated.

Statistical Analysis

Measurement and calculations obtained were statistically analyzed. Percentage (%), mean and standard deviation were used for descriptive data. Data normality was evaluated using the Kolmogorov-Smirnov test. Comparison of normally distributed data was conducted using Student's t test. The analysis was conducted using SPSS v. 21.0 (IBM Corp., Armonk, NY, USA).

Ethical Approval

Ethics Committee approval for the study was obtained.

Results

The median age of patients included in the study was 41.6 (22 - 59) years, of which 10% were male and 90% were female. An example case is shown in Figure 1, which shows a diagram of the methods of femur length measurement, as well as some of the horizontal sections at various levels where the canal diameter was measured. Femoral measurement data are shown in Table 1. The acetabulum measurement diagram of a sample case is shown in Figure 2. Acetabulum measurements are shown in Table 2.

The mean of FM 4 was 33.61 degrees on the normal side and 26.38 degrees on the dislocated side, although the difference was not statistically significant.

When the angulation of the minor trochanter, the diameter of the mediolateral canal in the middle of the femur, the diameter

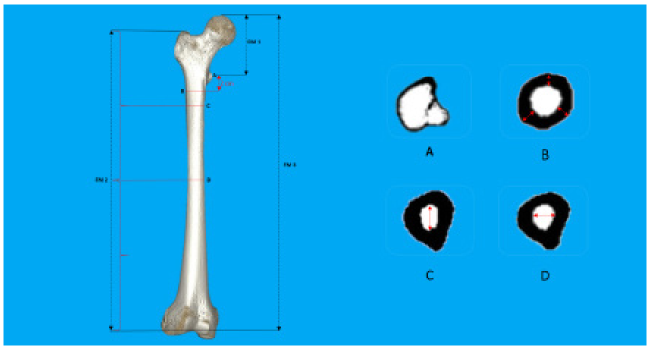

Figure 1. Femoral length measurement methods chart and sample horizontal cross sections.
A: Section from the level of trochanter minor
B: Section 2 cm distal to the trochanter minor (cortical thickness sample measurements)
C: Level of the proximal quarter of the distance between the trochanter major notch (FM 10)
D: Half the distance between the trochanter major notch (FM 7)

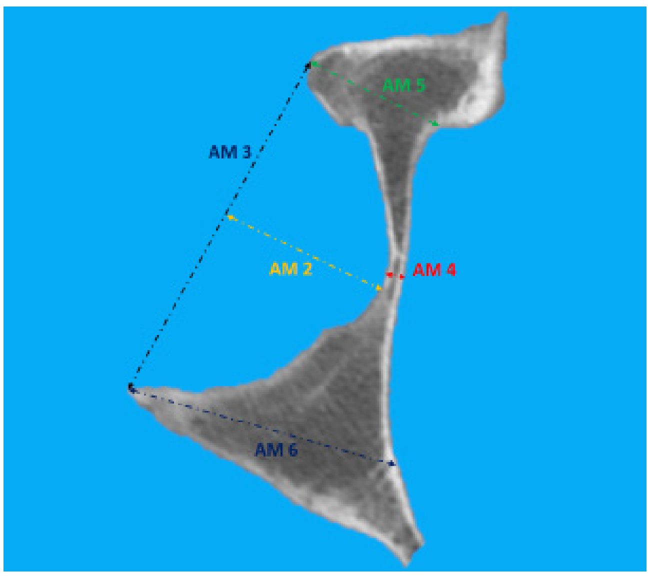

Figure 2. Acetabulum length measurements chart.

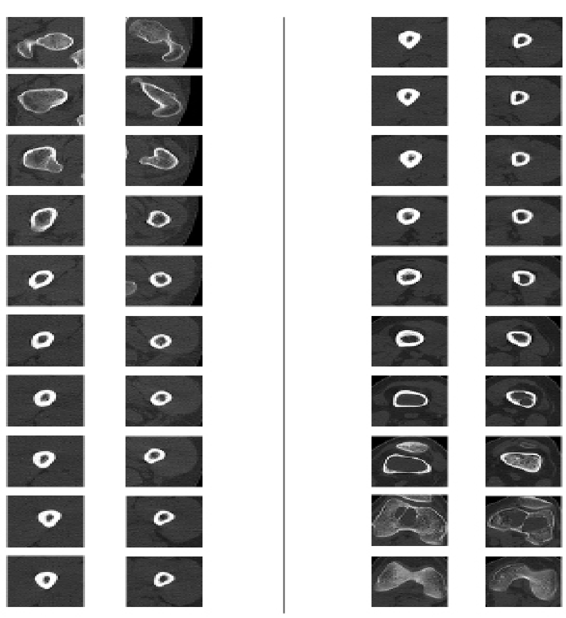

Figure 3. Images of both femurs in axial sections 2 cm apart from the level of the trochanter major, progressing distally.

Table 1. Comparison of femoral measurements.

FM	Side	Min. -Max. (mm-degree)	Ave. ± SD	p-value
1	Normal	62.6-73.8	69.15±3.83	0.000
	Dislocated	45.0-65.0	57.04±7.16	
2	Normal	380.4-418	395.96±12.51	0.796
	Dislocated	383.0-410.0	394.6±10.5	
3	Normal	393.6-440.0	414.42±15.23	0.315
	Dislocated	390.7-429.0	407.58±14.32	
4	Normal	20.6-76.9	33.61±16.13	0.383
	Dislocated	2.6-70.1	26.38±19.8	
5	Normal	7.03.2029	19.58±6.43	0.000
	Dislocated	15.7-56.33	39.6±12.83	
6	Normal	9.3-25.6	12.51±4.71	0.333
	Dislocated	9.7-28.3	14.71±5.19	
7	Normal	5.2-9.8	8.92±1.05	0.009
	Dislocated	8.4-14.7	10.99±1.98	
8	Normal	21.1-36.9	29.96±4.79	0.779
	Dislocated	21.1-60.7	28.81±11.81	
9	Normal	38.3-43.9	40.48±1.87	0.015
	Dislocated	14.9-44.3	31.57±9.36	
10	Normal	10.2-18.9	13.59±2.58	0.097
	Dislocated	13.0-17.9	15.25±1.52	
11	Normal	8.9-13.0	10.91±1.1	0.274
	Dislocated	9.7-18.0	11.88±2.47	
12	Normal	5.3-8.9	7.42±1.01	0.011
	Dislocated	7.6-14.6	9.4±1.95	
13	Normal	104.0-157.0	126.73±16.26	0.943
	Dislocated	98.0-153.0	127.33±20.43	
14	Normal	5.3-7.1	6.01±0.59	0.000
	Dislocated	4.0-5.7	4.8±0.61	
15	Normal	11.6-20.5	15.23±2.68	0.523
	Dislocated	13.3-18.9	14.51±2.19	
16	Normal	9.7-14.6	12.10±1.42	0.496
	Dislocated	8.7-14.0	11.49±2.0	

Table 2. Comparison of acetabular measurements.

AM	Side	Min. -Max. (mm-degree)	Ave. ± SD	p-value
1	Normal	19,3-42,2	28,15±7,17	0,34
	Dislocated	6,2-38,3	24,24±10,38	
2	Normal	19,4-30	23±2,72	0
	Dislocated	11,2-18,5	15,29±2,46	
3	Normal	43,8-52,5	48,11±2,66	0
	Dislocated	22,2-36,5	30,33±4,04	
4	Normal	1,2-7,8	3,77±2,3	0,671
	Dislocated	1,1-9,3	4,27±2,89	
5	Normal	21,8-31,1	26,17±2,91	0
	Dislocated	29,2-36,6	32,91±2,29	
6	Normal	17-22,7	20,1±1,61	0
	Dislocated	22-31	25,56±2,96	
7	Normal	17,5-35,2	25,82±4,74	0
	Dislocated	6,3-20,6	11,21±2	

of the mediolateral canal at the level of the trochanter minor, the diameter of the narrowest canal of the femur, and the cortex thickness values 2 cm distal to the trochanter minor were compared between normal and dislocated hip, a statistically significant difference was found.

Average FM 14 was 1.25 times greater on the normal side compared to the dislocated side.

The distance between the trochanter minor and the intercondylar notch of the femur was calculated as 345.27 mm on the normal side and 350.54 mm on the dislocated side. On average, the distance on the dislocated side was 5.27 mm longer.

Figure 3 shows the level- by- level changes in the comparative images of 2 cm-spaced axial sections from the trochanter major to the level of the intercondylar notch on the dislocated and intact hip sides of one patient.

A statistically significant difference in acetabulum depth, anterior posterior diameter of acetabulum, anterior lip thickness, posterior lip thickness, and acetabulum volume was identified when normal and dislocated hip measurements were compared. The mean acetabulum depth on the normal side was 1.50 times that of the dislocated side, the normal side's mean anterior-posterior diameter was 1.58 times that of the dislocated side, the normal side's mean anterior lip thickness was 2.33 times that of the dislocated side, and the normal side's average posterior lip thickness was 3.61 times that of the dislocated side. The average acetabulum volume on the normal side was 25.82 cm3 and 11.21 cm3 on the displaced side. The intact side acetabulum volume was found to be 2.30 times that of the dislocated side.

Discussion

Total hip arthroplasty (THA) surgery performed in the treatment of degenerative osteoarthritis caused by DDH is very challenging and has a high complication rate due to existing large bone deformities [7,9,12].

The femoral length was found to be 6.84 mm shorter on the dislocated side. Similar to our results, an average of 9 mm shortness was reported in a similar study [13].

Although the entire femur length is shorter on the dislocated side, this shortness is attributed to the portion proximal trochanter minor, and the situation is inverted distal to the trochanter minor, with the femur length distal to the trochanter minor being longer in the dislocated hip when compared to the normal side. The distal side of the trochanter minor was, on average, 5.27 mm longer on the dislocated side compared to the normal side. We believe that this finding is critical for precise leg length modification in THA applications.

Femoral anteversion angles have been reported in the literature as being 13 degrees in normal hips, 38.4 degrees in Crowe Type 3-4 hips, 37 degrees in Crowe Type 4 hips, an average of 22.2 degrees in CHD, 41 degrees in Crowe type 4a hips, and 29 degrees in Crowe type 4b hips [12-16]. In our study, femoral anteversion angles were found to be 33.61 degrees on the normal side and 26.38 degrees on the dislocated side, and these values demonstrate increased femoral anteversion similar to other studies on DDH hips. However, the variability of the angles suggests that it may be caused by the pressure of the pelvis on the dislocated femoral head at different angles in different positions. The values for the normal side in our study indicate a higher femoral anteversion than the measurements in normal hips in other studies [12,13,15,16]. These findings suggest that the dislocated side may impact the intact hip over time, or that the excess of femoral anteversion in the normal hips may be substantial from the beginning.

When the rotational position of the trochanter minor relative to the distal femur was examined, it was discovered that it was substantially retroverted in the dislocated hip joint. This was assumed to be owing to the variable anatomical structure and placement of the proximal femur in DDH patients, as well as the diversity of the iliopsoas muscle's angle of attraction on the trochanter minor. We believe this is critical and should not be overlooked during THA.

One study reported that the intramedullary anteroposterior diameter was greater than the mediolateral diameter at the isthmus level in both normal and dysplastic femurs, and the trochanter minor was 40 mm distal and the mean anteroposterior canal diameter was greater than the mediolateral diameter at the isthmus level in Crowe Type 3-4 patients [13,15]. In our study, the mediolateral diameter was observed to be larger than the anteroposterior diameter on both the dislocated and normal sides at the level of the trochanter minor. Both on the dislocated and on the normal side, the anteroposterior diameter was larger than the mediolateral diameter at all levels, distal to the trochanter minor.

The diameter of the femoral intramedullary canal is one of the most significant features for prosthesis fixation and plays an important role in the selection of the suitable prosthesis prior to the operation and, therefore, in stability [17]. A study reported that all canal diameters in Crowe 4 patients were found to be smaller than in the normal control group [12]. Similarly, we discovered that the canal width in the proximal was narrower in both directions compared to the normal side. The diameter of the femoral canal was observed to be wider on the dislocated side compared to the normal side as it progressed distally from 20 mm below the trochanter minor, contrary to the literature findings. It will be very helpful to know that the femoral canal can be of varying widths at various levels in order to minimize issues with femoral stem fixation distal to the osteotomy line, especially in patients who require femoral shortening after THA. In many studies, canal diameters at the isthmus level were found to be narrower on the dislocated side [12,13,15]. The canal diameter of the dislocated side at the isthmus level was found to be substantially larger than that of the normal side in our study. We believe this is due to the differentiation in the normal bone growth of the femur as a result of the patients' impairment of load distribution in the extremities due to DDH.

The dislocated femur in adults with unilateral high hip dislocation is hypoplastic when compared to the normal side [18]. In these patients, decreased canal width and thin cortical thickness may result in femoral fractures during THA [7,8]. The dislocated side was observed to have a substantially thinner mean cortical thickness at a level of 20 mm distal to the trochanter minor. The degradation of various functions, ranging from body posture to gait physiology, caused by high dislocations allows patients to place less strain on the extremities on the dislocated side, resulting in insufficient bony development on that side. The femurs of Crowe type 4 DDH patients were compared to other DDH femurs in a study, and it was reported that the femoral structures of high dislocation patients were significantly different, and therefore the readily available prostheses may not be the best option for these patients [19]. This should be taken into consideration during THA and precautions should be taken against possible femoral fracture complications.

A reduced hip joint is very important for the natural development of the anatomical structure of the acetabulum, and the normal acetabular anteversion angle has been found to be 20, 19.9, 23, 21.3, 21.4 degrees in different studies [10,14,20-22]. In our study, the acetabular anteversion angle in the reduced hips patients with unilateral dislocation was observed to be 28.15 degrees, higher than similar reports in the literature. This finding demonstrates that the developmental process of the normal hip may be affected in patients with high hip dislocation on one side or that the normal hip joint may have minor acetabular dysplasia.

Acetabular anteversion values for hips with DDH have been reported to be 22 degrees for Crowe Type 2 hips, 24.4 degrees for hips with DDH, and 34 degrees for Crowe Type 4 hips [11,14,23]. In our study we found an average acetabular anteversion angle of 24.24 degrees, similar to reports in the literature.

In patients with high hip dislocation, the pelvic bones on the dislocated side are smaller and the acetabulum walls are thinner than those on the normal side [13,23]. The acetabular length, height, width, and depth of DDH hips were shown to be substantially smaller than those of normal persons when compared to those with Crowe type 4 CHD [23]. Similar to previous reports, we found that in dislocated hips, the anterior-posterior diameter, anterior lip and posterior lip thickness, and depth of the dislocated acetabulum were smaller and thinner when compared to those of the normal side. When comparing the normal side to the dislocated side, the largest anatomic defect was observed in the posterior lip thickness.

Inappropriate application of the acetabular component during THA is complicated by acetabulum variations in terms of both volume and bone structure [11,14,20,23,24]. A study comparing Crowe type 4 DDH to normal people discovered that normal hip volume was more than four times that of those with DDH [23]. The volume of the acetabulum of the normal side was found to be 2.3 times that of the dislocated side in our study. This considerable difference highlights the importance of a reduced hip joint in acetabulum volumetric development and hence the forces transferred to the acetabulum.

Our research has some limitations. Our study included a relatively small number of patients. It should be noted, however, that adult patients with a high dislocation on one side (Hartoflakidis classification C) and a normal side on the other side are quite rare. The study's most notable aspect is that it is the first extensive research of its kind undertaken in our country. The study can be advanced in the future by increasing the number of patients, adding subgroups, adding other systemic disease parameters, and including different angles and ratios.

Conclusion

Changes in both the dislocated and normal sides were revealed in patients with unilateral high DDH, and the measures differed significantly. Since the normal hips of the patients in our study differed from the typical hip values in the literature, it was assumed that the other hip joints of the patients with DDH in one hip should be addressed with caution.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

The authors declare no conflict of interest.

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